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Duane Arnold Energy Center

CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY ANNUAL REPORT

January 1999 – December 1999

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INTRODUCTION

This report presents the results of the physical, chemical, and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 26th year of station operation (January 1999 to December 1999).

The Duane Arnold Energy Center Operational Study was implemented in mid-January, 1974. Prior to plant start-up extensive preoperational data were collected from April, 1971 to January, 1974. These preoperational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of the 25 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long-term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by Alliant Energy (formally I.E.S. Utilities Inc.), is located on the west side of the Cedar River, approximately two and one-half miles north-northeast of Palo, Iowa, in Linn County. The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power (1658 MWth) at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers which required a maximum of 11,000 gpm (ca. 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (ca. 15.5 cfs) may be lost through evaporation, while 4,000 gpm (ca. 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical, and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These preoperational studies are described in earlier reports.[1-3] Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as to assess the magnitude of impingement of the fishery on intake screens. These were first implemented in January, 1974 and have continued without interruption through the current year.[4-28]

The specific objectives of the operational study are twofold:

1. To continue routine water quality determinations in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.
2. To conduct physical, chemical, and biological studies in and downstream of the discharge canal and to compare the results with similar studies executed above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities downstream of the discharge.

STUDY PLAN

During the operational phase of the study sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): 1) upstream of the plant at the Lewis Access Bridge (Station 1); 2) directly upstream of the plant intake (Station 2); 3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3); and 4) adjacent to Comp Farm, located about one-half mile below the plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering of the University of Iowa. From January, 1979 through December, 1983 samples were collected an analyzed by Ecological Analysts, Inc. Since 1984 collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analyses. Samples for routine physical, chemical, and biological analysis were taken twice per month, while other studies were conducted seasonally. The following are discussed in this report:

I. General Water Quality Analysis

A. Frequency: twice per month

B. Location: at all five stations

C. Parameters Measured:

1. Temperature
2. Turbidity
3. Solids (total, dissolved, and suspended)
4. Dissolved oxygen
5. Carbon dioxide
6. Alkalinity (total and carbonate)
7. pH
8. Hardness series (total and calcium)
9. Phosphate series (total and ortho)
10. Ammonia
11. Nitrate
12. Iron
13. Biochemical oxygen demand
14. Coliform series (fecal and E. coli)

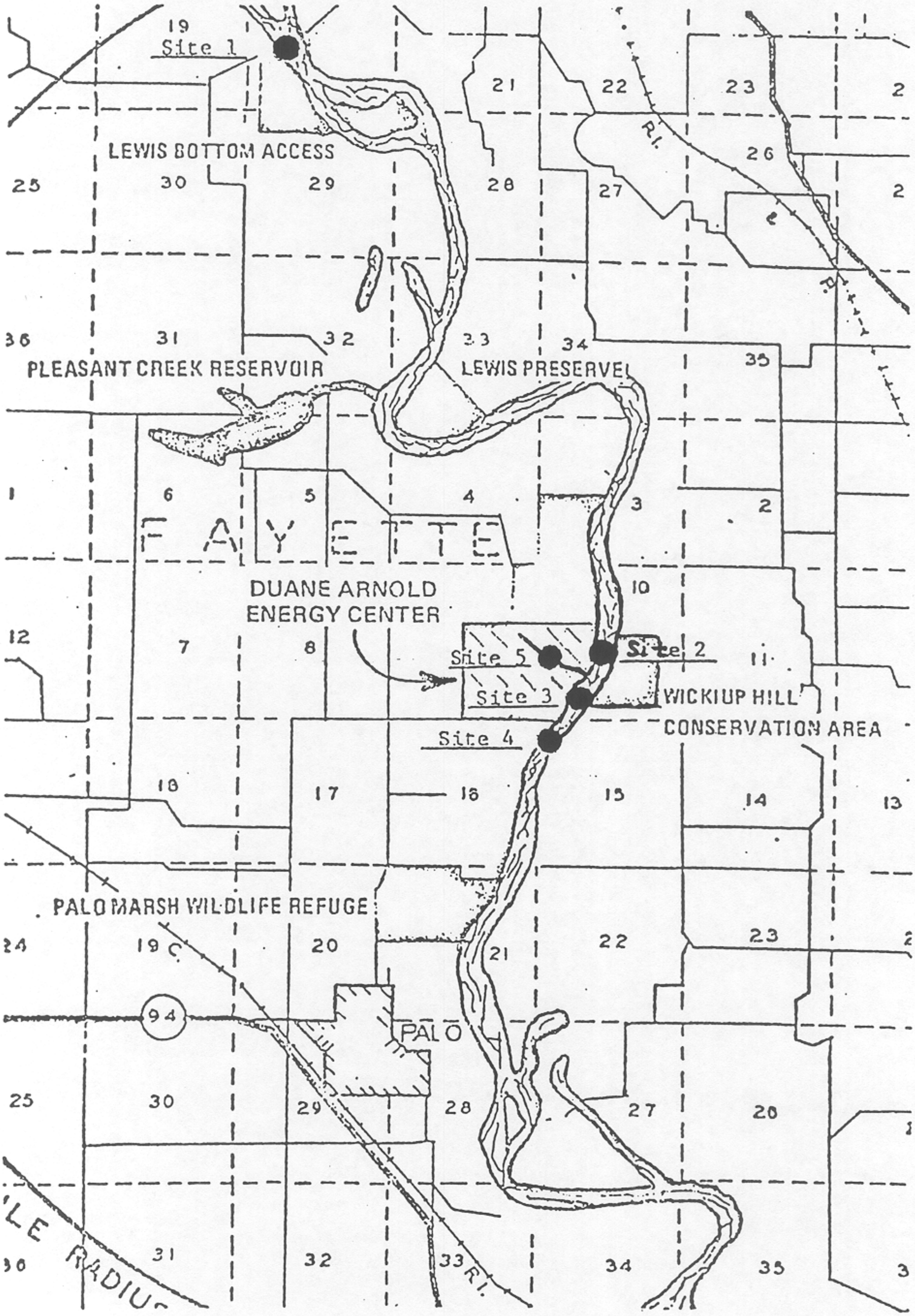

Figure 1. Location of Operational Sampling Sites

II. Additional Chemical Determinations

A. Frequency: twice yearly (April and July)

B. Locations: at all five stations

C. Parameters Measured:

1. Chromium
2. Copper
3. Lead
4. Manganese
5. Mercury
6. Zinc
7. Chloride
8. Sulfate

III. Biological Studies

A. Benthic Studies:

1. Frequency: Ponar grabs and artificial substrates at intervals May, August, September, October
2. Location: at all five stations

B. Impingement Studies:

1. Frequency: daily
2. Location: intake structure

C. Asiatic Clam (Corbicula) and Zebra Mussel (Dreissena) Surveys:

1. Frequency: twice yearly (May and September)
2. Location: upstream and downstream of the plant, intake bay, cooling tower basin, and discharge canal. The Zebra mussel survey also included Pleasant Creek Reservoir.

OBSERVATIONS

Physical Conditions

Hydrology (Table 1 and 2)

Mean river discharge for 1999 was 7,786 cfs, somewhat higher than that present in 1998 due to the extremely high flows present in May and July when mean discharges were over 400% greater than the mean monthly averages. River flows for the last three months of 1999 were well below those present during the same period of 1998. The 1999 mean flow was the highest mean flow observed since 1993 and the third highest observed since the Cedar River water quality study was implemented in 1972.

Mean monthly discharge at the U.S. Geological Survey gauging station in Cedar Rapids ranged from 1,341 cfs in December to 17,930 cfs in July. Flows in excess of the 1903-1996 median monthly average occurred in all months except March and from October through December. The lowest daily flow of 290 cfs, occurred on December 22 while a maximum daily discharge of 58,700 cfs occurred on July 25.

River flows varied from ca. 2,400 to 5,000 cfs from January through early February and then increased to a winter maximum of 7,230 cfs on February 13. From late February through early April flows never exceeded 5,000 cfs but increased rapidly by mid-April to peak at 18,500 cfs on April 28. High flows continued from May through early August ranging from ca. 9,000 to 58,000 cfs. Flows declined sharply by mid-August and by late September were below 2,800 cfs. Hydrological data are summarized in Table 1.

Estimated mean flow in the Cedar River on the days when samples were collected are given in Table 2. The average of these flows is 7,737 cfs similar to the mean river discharge of 7,786 cfs present for the year. Hydrological conditions present during sampling were very representative of conditions present throughout the year.

<u>Temperature</u> (Table 3)

In 1999, temperatures ranged from 0.0°C (32.0F) in early January at all river locations to 26.0°C (78.8°F) at Station 2 on July 22. The maximum temperature observed was identical to that present in 1998[28]. A maximum downstream temperature of 26°C (78.8°F) was also observed at Station 3 on July 22. The highest discharge canal temperature observed during the 1999 study was 31.0°C (87.8°F) also on July 22.

Station operation continued to have a negligible effect on downstream water temperatures. A maximum temperature differential (ΔT) between upstream temperatures at Station 2 and downstream at Station 4 of 1°C (1.8°F) was measured on several occasions. A maximum temperature differential between the ambient river and the discharge canal (Station 5) observed during the 1999 study was 10.0°C (18°F) on both October 5 and December 15. Obviously there were no observed instances in which downstream river temperatures exceeded upstream river temperatures by more than the Iowa Water Quality standard of 3°C[29]. A summary of water temperature differentials between upstream and downstream locations is given in Table 4.

Turbidity (Table 5)

Average river turbidity values during 1999 were the highest observed since 1993 (Table 27), due largely to high peak values of 260 to 340 NTU in early May. High values of 140 NTU were also observed in early July. Low values of 1 to 2 NTU occurred in January.

Turbidity values in the discharge canal exhibited considerable fluctuation: a high value of 420 NTU was observed in early July. Low values of 1 to 2 NTU occurred in January and early February.

Solids (Table 6-8)

Solids determination included total, dissolved and suspended. Total solids values in upstream river samples in 1999 were generally similar to those observed in 1998. A maximum value of 570 mg/L occurred in May during a period of extremely high river flow. Low total solids values of 320 to 330 mg/L occurred in September and October.

Dissolved solids values in the upstream river were similar to those present in 1998 ranging from 180 mg/L in late July to 380 mg/L in January. Dissolved solids in the discharge canal were usually much higher than in the river, ranging from 280 mg/L in November when the station was off line to 2,100 mg/L in August. As in most previous years, dissolved solids values at downstream locations were slightly higher than levels observed upstream ranging from 190 to 410 mg/L. Low suspended solids of 2 to 3 mg/L occurred in January. A high value of 310 mg/L occurred on May 19 during a period of extremely high flow. Suspended solids values in the discharge canal exhibited considerable variation. Low values of 3 mg/L were present in December while a high value of 480 mg/L occurred in early July.

Chemical Conditions

Dissolved Oxygen (Table 9)

Dissolved oxygen concentrations in river samples collected in 1999 ranged from 6.8 in July to 16.0 mg/L in December (82 to 119% saturation). Dissolved oxygen concentrations of 12.0 to 15.3 mg/L (98 to 115% saturation) were consistently present from January through early April. Concentrations varied from ca 7 to 9 mg/L from early May through mid-August and then increased ranging from ca 10 to 16.0 mg/L (111 to 119% saturation) for the remainder of the year. Lowest concentrations were observed in July. Unlike 1998 supersaturated dissolved oxygen concentrations associated with algal photosynthesis were frequently observed during 1999.

Dissolved oxygen concentrations in the discharge canal (Station 5) were consistently lower than river levels. Discharge canal concentrations ranged from 4.6 mg/L (58% saturation) in mid-August to 13.8 mg/L (95% saturation) in early January. Differences in dissolved oxygen concentrations at upstream and downstream locations were minimal and station operation appeared to have no significant impact on dissolved oxygen concentrations below the plant.

Carbon Dioxide (Table 10)

Except for January and February carbon dioxide concentrations were low throughout 1999. Maximum values of 10 to 13 mg/L were present in late January and early February. Minimum values of 1 mg/L or less occurred from September through December. Concentrations in the discharge canal could only rarely be determined but, based on pH values, were doubtlessly higher than river levels.

Alkalinity, pH, Hardness (Tables 11-15)

These interrelated parameters are influenced by a variety of factors including hydrological, climatic and biological conditions.

Total alkalinity values in the 1999 river samples were generally high in the winter and declined during periods of high flow. Values ranging from 98 mg/L in May during a period of extremely high river flow to 250 mg/L in January. Total alkalinity values in the discharge canal ranged from 102 to 266 mg/L.

Carbonate alkalinity was rarely present in river samples from January through mid-August. The highest carbonate value 18 mg/L, occurred in October. Values of 6 to 18 occurred from late September through December. Carbonate alkalinity was only observed on four occasions in the discharge canal.

Values for pH in river samples in 1999 ranged from 7.7 to 9.0. Values of less than 8 units were only rarely present in river samples. Highest pH values of 8.5 to 9.0 occurred from late September through December when river flows were low. Values for pH in the discharge canal ranged from 7.5 to 8.8.

Average total hardness values in the 1999 upstream river samples were substantially lower than those present in 1998 (Table 28) and generally exhibited a pattern similar to that observed for total alkalinity. Lowest values of 120 to 170 mg/L occurred in May and July when river discharge was high. Levels of 290 to 320 mg/L were present in January and December. Calcium hardness values paralleled total hardness values. Low values of 80 mg/L occurred in July. High values occurred in January, March and December.

Hardness values in the discharge canal continued to be consistently higher than levels present in the river; a result of reconcentrations in the blow down from the towers. Total hardness values in the discharge canal ranged from 260 to 1,400 mg/L. As a result of high hardness values in the discharge canal, downstream levels were usually slightly higher than those present upstream (Table 27).

<u>Phosphates</u> (Table 16 and 17)

Phosphate concentrations in the 1999 samples were lower than those present in all but one year of the 1972 to 1999 study (Table 28). Total phosphate concentrations of 0.1 mg/L or less were common from late September through December. Highest values of 0.7-0.8 mg/L were observed on one occasion in May. Levels in the discharge canal were consistently higher than river levels ranging from 0.1 to 3.1 mg/L.

Orthophosphate concentrations in the river samples ranged from 0.4 mg/L in July to <0.1 mg/L from late August through December. Orthophosphate concentrations in the discharge canal ranged from <0.1 to 1.7 mg/L.

Ammonia (Table 18)

Ammonia concentrations in the 1999 river samples remained very low throughout the year. Maximum concentrations, 0.2 mg/L (as N) occurred in January. Values of less than 0.1 mg/L (as N) were consistently present from April through December. Ammonia concentrations in the discharge were generally slightly higher, ranging from <0.1 to 0.5 mg/L (as N).

Nitrate (Table 19)

Average nitrate concentrations in river samples were slightly lower than those present in 1998 (Table 28) due primarily to the low values present from late September through December. Low values of 2.6 to 3.0 mg/L (as N) were present in November. Maximum nitrate concentrations of 12 mg/L (as N) were present in April.

Nitrate concentrations in the discharge canal were almost always higher than river levels. A maximum nitrate concentration of 81 mg/L (as N) was observed in the discharge canal on June 21 but downstream effects were minimal.

Iron (Table 20)

Iron concentrations in the 1999 river samples continued to be high. Concentrations ranged from 0.09 mg/L in January to 15 mg/L in May. As in previous years, high iron concentrations frequently accompanied increased turbidity and suspended solids levels indicating that most of the iron was in the suspended form rather than in solution. Iron levels in the discharge canal were usually slightly higher than river levels ranging from 0.21 to 22 mg/L.

Biological Studies

Biochemical Oxygen Demand (Table 21)

Five day biochemical oxygen demand (BOD_5) values in the 1999 river samples were similar to those present in 1998 but well below the levels present from 1994 to 1997 (Table 28). Maximum BOD levels (9 to 11 mg/L) occurred in late September. High values, associated with runoff, were not observed in 1999. Low values of <1 mg/L were present at intervals in January, February, March, April and December. BOD levels in the discharge canal were generally similar to those present at river locations.

Coliform Organisms (Tables 22 and 23)

Coliform determinations included enumeration of fecal coliforms as well as specific determination of Escherichia coli.

Maximum river concentrations of fecal coliform of 4,300 organisms/100 ml were observed downstream of the discharge canal (Station 3) on July 22. High coliform levels were also present at the upstream locations on this date. Maximum E. coli levels 2,000 organisms/100 ml occurred in June and July when river discharge was very high. Both fecal coliform and E. coli concentrations exhibited wide fluctuations during the year. Lowest values, <10 to 20 organisms/100 ml, were present in March and November.

Extremely high fecal coliform and E. coli concentrations were not observed in the discharge canal in 1999. Maximum fecal coliform and E. coli concentrations of 9,500 and 2,200 organisms/100 ml respectively were observed on July 6.

ADDITIONAL STUDIES

In addition to the routine twice monthly studies, a number of seasonal limnological and water quality investigations were conducted in 1999. The studies discussed here include additional chemical determinations, benthic surveys, Asiatic clam (Corbicula) and zebra mussel (Dreissena) surveys and impingement surveys.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on April 15 and July 6, 1999 from all river locations and in the discharge canal and analyzed for chloride, sulfate, chromium, copper, lead, maganese, mercury and zinc. Concentrations of all parameters fell within the expected ranges.

Chloride and sulfate concentrations were similar at all river locations on both sampling dates and also similar to values observed in 1997 and 1998[27,28]. In 1999, chloride concentrations in river samples ranged from 11 to 24 mg/L. Sulfate concentrations ranged from 14 to 32 mg/L.

Levels of the heavy metals chromium, copper, lead and mercury were below detection limits in all river samples. Manganese values in the river ranged from 80 to 100 ~~90~~ ug/L in April to 150 ug/L in July. Levels of zinc exhibited considerable fluctuation ranging from less than 20 ug/L in July to 60 ug/L upstream (Station 1) on April 15.

Reconcentration of solids in the blowdown from the cooling towers resulted in increased levels of chlorides, sulfates, manganese and zinc in the samples from the discharge canal but downstream increases were negligible. Sulfate concentrations present in the discharge canal on both sampling dates were substantially higher than those present in 1998[28]. The results of additional chemical determinations are presented in Table 24.

Benthic Studies

Artificial substrate samplers (Hester-Dendy) were placed at each of the four sampling locations, upstream and downstream of the discharge canal and in the discharge canal on August 18 and

September 23, 1999. These substrates were collected on September 23 and October 29, 1999 following a five week period to allow for the development of a benthic community.

As in past studies, the benthic communities which developed on the substrates were much larger and more diverse than those found in the shifting sand and silt bottom characteristic of the Cedar River in the vicinity of the Duane Arnold Energy Center. Ponar grab samples taken from the five sites contain few if any benthic organisms, but a diverse assemblage of organisms develop on the substrates during the six week colonization period.

In 1999 a total of 30 taxa were identified during the two sampling periods, 28 in September and 25 in October. These included 26 species (5 orders) of insects, one annelid, one isopod, one nematode and one flatworm. Chironomid larvae (Diptera) were the dominant organisms in both the September and October samples.

Both the total numbers and diversity of organisms in the discharge canal continued to be far lower than in the river. Only 3 taxa; three in September and two in October were present. A total of 1,549 organisms, 19 in September and 1,530 in October were present on the discharge canal substrates. The October discharge canal samples consisted primarily of tubificid worms.

In general, there was little difference in the composition of benthic populations between upstream and downstream locations in the August studies although total numbers were slightly higher at the upstream locations. The composition of the benthic population at the river locations were similar but total number of organisms were higher in the September samples. The substrates from the Lewis Access site (Station 1) could not be recovered in the September study.

As in prior years the artificial substrate studies indicate that the Cedar River, both upstream and downstream of the Duane Arnold Energy Center is capable of supporting a relatively diverse benthic macroinvertebrate fauna in those limited areas where a suitable substrate is available. The discharge canal however, is not a suitable habitat for most benthic organisms. The results of the benthic studies are presented in Table 25.

Asiatic Clam and Zebra Mussel Surveys

In past years a number of power generation facilities experienced problems with blockage of cooling water intake systems by large numbers of Asiatic clams (Corbicula sp.). Although this clam commonly occurs in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy center. Corbicula has not been collected from the Cedar River in the vicinity of the DAEC during the routine monitoring program, which was implemented in April of 1971. A single Corbicula was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because Corbicula has been reported on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No Corbicula were collected during the 1981 to 1998 investigations[11-28]. The zebra mussel (Dreissena polymorpha) is a European form which was first found in the United States in Lakes St. Clair and Erie in 1988. The zebra mussel has been a major problem at many power plant intakes as well as a number of municipal water treatment plants in the United States. The organisms tend to grow in clumps attached to a solid substrate and can rapidly clog intake structures, screens, and pipes. It is difficult to control chemically and frequently must be removed mechanically. The mussel is adapted to both river and lake habitats and does especially well in enriched waters which support large plankton populations that it utilizes as food. Unlike the Asiatic clam (Corbicula), it is capable of living in cold waters and does not require a silty substrate.

Since its introduction into the United States the zebra mussel has rapidly expanded its range. It is now found in all of the Great Lakes. In 1991, just three years after they were first found in the U.S., they were collected in the Hudson, Illinois, Mississippi, Ohio, Susquehanna, Tennessee, and Cumberland Rivers[30]. The U.S. Army Corps of Engineers reports that zebra mussel populations have increases exponentially on lock and dam surfaces since their introduction into the Mississippi River in 1991[31,32] and the organism has also established itself at several locations in the Iowa reach of the Mississippi River. Zebra mussel populations increased rapidly in the

Iowa reach of the Mississippi River in 1994 and 1995 but populations appear to have remained relatively constant during 1999 and the zebra mussel has not been observed in the Iowa tributaries of the Mississippi River. Zebra mussels were observed in the Iowa reach of the Missouri River in 1999 but do not appear to have expanded to tributary streams[33].

Additional studies were conducted by the University of Iowa Hygienic Laboratory in May and September 1999 to determine if either Asiatic clams or zebra mussels were present in the vicinity of the Duane Arnold Energy Center. Sampling was carried out upstream and downstream of the station, in the intake bay, the cooling tower basin and discharge canal as well as in the Pleasant Creek Reservoir utilizing a mussel rake and Ponar sampler, as well as visual inspections of appropriate substrates. No Asiatic Clams or zebra mussels were found at any of the sites of during the 1999 investigations.

Impingement Studies

The total number of fish impinged on the intake screens at the Duane Arnold Energy Center during 1999 as reported by Alliant personnel, remains very low. Daily counts indicated a total of only 412 fish were impinged during 1999. Highest impingement occurred in February and March when a total of 336 fish, or approximately 82% of the yearly impingement total, were removed from the trash baskets. Lowest impingement rates occurred from September through November when only 3 fish were removed from the trash baskets. The month with the highest impingement rate was March when 187 fish were collected in the trash baskets. The results of the daily trash basket counts are given in Table 26.

DISCUSSION AND CONCLUSIONS

The Cedar River Baseline Ecological Study which began in April 1971 terminated in December 1999. During the 28 ½ years of the study an extensive data base has been compiled relative to the impact of a variety of factors on the water quality and limnology of the Cedar River. The

Duane Arnold Energy Center became operational in 1974 and the effects of operation of the station on the Cedar River have been closely monitored since that time.

Although minor impacts on water quality have at times been detected downstream of the discharge, the effects have been minimal and there has never been any evidence of significant or long term impacts on the water quality or biota of the Cedar River. The effects most commonly observed include slight increases in water temperature, dissolved solids, hardness, phosphates, nitrates and iron, A similar pattern was present during the current years study (Table 27). As might be expected. Greatest downstream increases usually occurred in low flow years while differences during years with high flows were less apparent.

During 1999 the mean discharge in the Cedar River was 7,786 cfs. This flow was somewhat higher than the 1998 mean flow of 6,024 cfs and the fourth highest flow present since the Cedar River water quality was implemented. Flows in excess of the 1903-1996 median monthly average occurred from January through September. Maximum flows occurred in May with extremely high flows persisting through early August. Average discharge from the cooling towers into the Cedar River is only about 9 cfs and as expected the station had a negligible impact on downstream water temperatures. A maximum observed temperature differential (ΔT) between upstream temperatures at Station 2 and Station 4 located one half mile downstream of the plant of 1.0°C (1.8°F) was observed on only three occasions in 1999. No other observed temperature differentials ever exceeded 0.5°C (0.9°F).

As previously mentioned station operation also had minimal impact on other water quality parameters. Several parameters exhibited slight increases in concentration downstream of the station but these increases were not sufficient to adversely impact aquatic life or violate applicable water quality standards.

Additional chemical determinations conducted in April and July 1999 exhibited low concentrations of heavy metals in both the upstream and downstream river samples none of which exceeded the Iowa Water Quality standards[29]. Heavy metal concentrations in the mixing zone (Station 3) downstream of the station were similar to those observed at upstream locations.

Reconcentration in the blowdown from the cooling towers resulted in increased concentrations of maganese, zinc, chlorides and sulfates in the discharge canal but downstream effects were negligible. The extremely high sulfate levels present in the discharge canal were the result of the addition of sulfuric acid to the cooling towers for pH control (Table 24).

In general the water quality of the Cedar River during the 1999 reflected the climatic and hydrological patterns present and it appears that these conditions as well as agricultural activities in the river basin are the major factors affecting the limnology and water quality of the Cedar River.

Runoff from agricultural land affects that water quality of the river in several ways. Ammonia based fertilizers are extensively used throughout the drainage basin and the oxidation of the ammonia to nitrate is responsible for the high nitrate levels observed throughout the course of the study (Table 28). These high levels have been especially evident since 1979 when mean yearly concentrations usually exceeded 5 mg/L (as N). Peak average levels of 8.6 mg/L (as N) were observed in 1983 a year characterized by heavy runoff and high river discharge. Mean yearly nitrate concentrations have exceeded 6 mg/L (as N) in six of the last ten years. Nitrate concentrations declined somewhat following the record flows present in 1993 which flushed much of the nitrate from the Cedar River basin but levels have gradually increased since that time. In 1999 maximum nitrate concentration of 12 mg/L (as N) were observed in April.

Runoff from agricultural land is also responsible for the elevated turbidity and suspended solids values frequently observed during periods of high river flow and it is likely the deposition of sediments from land runoff on the river bottom is largely responsible for the paucity of benthic organisms collected in ponar grab samples.

High concentrations of coliform organisms are commonly observed during periods of runoff and appear to be related to runoff from feedlots or other animal containment areas. This condition was especially evident during the current year when maximum concentrations of coliform organisms were present in May, June and July when extremely high river flows were present. It should be pointed out however that in past years, high coliform levels have also been observed during low flow periods possibly due to upstream point sources of pollution.

In past years high BOD values associated with snow melt and runoff from the river basin were frequently observed during the late winter and early spring period, but this condition was not observed during in either 1998 or 1999. Maximum BOD values of 9 to 11 mg/L resulting from the death and decay of large algal populations were observed in September. The average BOD value of 2.8 mg/L present in 1999 was similar to that observed in 1998 and was the third lowest value observed since the study commenced in 1972 (Table 28).

The numbers of fish impinged on the intake screens at the Duane Arnold Energy Center during 1999 remains extremely low. Only 412 impinged fish were reported in 1999. As in past years highest impingement rates occurred during the winter months. The impact of impingement on the fishery of the Cedar River continues to be insignificant.

Populations of benthic (bottom dwelling) organisms which colonized artificial substrates placed in the Cedar River in the summer and fall of 1999 were generally similar to those present in past years. Diversity was similar at upstream and downstream river locations and indicated that where adequate substrate is available the Cedar River is capable of supporting a diverse benthic biota. The paucity of organism normally present in the Cedar River in the vicinity of the Duane Arnold Energy Center is due to the shifting sand and silt bottom which does not provide a suitable substrate for bottom dwelling organisms.

The size and diversity of benthic populations developing on substrates placed in the discharge canal continue to be far smaller than those developing on the river substrates. Obviously the discharge canal does not provide a suitable habitat for most benthic organisms.

Since 1981 studies have been conducted to determine if the Asiatic Clam is present in the vicinity of the Duane Arnold Energy Center. Studies to determine if the zebra mussel is present have been conducted since 1991. Neither Asiatic clams nor zebra mussels have been observed during these investigations. Although zebra mussels are present in the Iowa reach of the

Mississippi River and have recently been observed in the Missouri River, populations appear to have remained relatively stable and the mussels have not been reported from any Iowa tributes to the Mississippi or Missouri River.

Table 1

Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1999

Date	Mean Monthly Discharge cfs	Percent of Mean Monthly Average†
January	3,365	269
February	5,136	313
March	4,223	70
April	11,360	169
May	19,280	401
June	16,000	294
July	17,930	422
August	7,745	318
September	3,249	148
October	2,015	82
November	1,789	73
December	1,341	71

*Data obtained from U.S. Geological Survey records
†Based on water years 1903-1996

Table 2

Estimated Mean Flows in the
Cedar River During Sampling in 1999

Date	Flows (cfs)
Jan-07	4,170
Jan-21	2,900
Feb-02	2,790
Feb-16	6,420
Mar-02	4,720
Mar-18	4,040
Apr-01	3,900
Apr-15	16,100
May-05	9,920
May-19	32,100
Jun-02	13,200
Jun-21	12,300
Jul-06	24,900
Jul-22	12,300
Aug-04	12,400
Aug-18	5,470
Sep-01	4,720
Sep-23	2,610
Oct-05	2,290
Oct-20	1,820
Nov-03	1,810
Nov-17	1,730
Dec-02	1,590
Dec-15	1,500

Table 3

Temperature (°C) Values for the Cedar River
near the Duane Arnold Energy Center during 1999

Date 1999	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 Feet Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan-07	0.0	0.0	0.0	0.0	0.0
Jan-21	0.5	0.5	7.5	1.0	1.0
Feb-02	0.5	1.5	7.5	1.0	2.0
Feb-16	2.5	2.5	6.5	3.0	3.0
Mar-02	4.5	4.5	9.0	4.5	4.5
Mar-18	6.5	7.5	13.5	7.5	7.5
Apr-01	14.5	14.5	20.0	14.5	14.5
Apr-15	10.5	10.5	19.5	10.5	10.5
May-05	17.0	17.0	24.5	17.0	17.0
May-19	16.0	16.5	21.5	16.5	16.5
Jun-02	18.5	18.5	24.0	18.5	18.5
Jun-21	20.0	20.0	27.5	20.0	20.0
Jul-06	25.0	24.5	26.0	24.5	25.0
Jul-22	25.0	26.0	31.0	26.0	25.5
Aug-04	24.0	24.0	27.0	24.0	24.0
Aug-18	22.5	23.0	27.0	22.5	22.5
Sep-01	20.5	21.5	26.0	21.5	21.5
Sep-23	15.5	16.0	25.5	17.0	17.0
Oct-05	10.0	10.0	20.0	10.0	10.5
Oct-20	9.0	9.5	13.0	9.5	9.5
Nov-03	7.0	7.0	10.5	11.0	7.5
Nov-17	5.5	5.5	7.5	7.0	6.5
Dec-02	3.5	4.0	12.0	4.0	4.5
Dec-15	2.5	2.5	12.5	3.0	3.0

Table 4

Summary of Water Temperature Differentials
and Station Output During Periods of
Cedar River Sampling in 1999

Date 1999	T (°C) Upstream River (Station 2) vs. Discharge (Station 5)	T (°C) Upstream River (Station 2) vs. Downstream River (Station 3)	T (°C) Upstream River (Station 2) vs. Downstream River (Station 4)	Station Output (% Full Power)
Jan-07	0.0	0.0	0.0	99.5
Jan-21	7.0	0.5	0.5	98.2
Feb-02	6.0	-0.5	0.5	100.0
Feb-16	4.0	0.5	0.5	100.0
Mar-02	4.5	0.0	0.0	100.0
Mar-18	7.0	1.0	1.0	99.9
Apr-01	5.5	0.0	0.0	99.9
Apr-15	9.0	0.0	0.0	99.9
May-05	7.5	0.0	0.0	99.9
May-19	5.0	0.0	0.0	100.0
Jun-02	5.5	0.0	0.0	99.9
Jun-21	7.0	-0.5	-0.5	99.9
Jul-06	1.5	0.0	0.5	100.0
Jul-22	5.0	0.0	-0.5	99.8
Aug-04	3.0	0.0	0.0	100.0
Aug-18	4.0	-0.5	-0.5	99.9
Sep-01	4.5	0.0	0.0	100.0
Sep-23	9.5	1.0	1.0	99.0
Oct-05	10.0	0.0	0.5	95.9
Oct-20	3.5	0.0	0.0	91.9
Nov-03	3.5	4.0	0.5	0.0
Nov-17	2.0	1.5	1.0	0.0
Dec-02	8.0	0.0	0.5	58.6
Dec-15	10.0	0.5	0.5	100.0

Table 5

Turbidity (NTU) Values for the Cedar River near the Duane Arnold Energy Center during 1999

Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	2	2	39	2	2
Jan-21	1	2	6	2	2
Feb-02	3	2	11	2	2
Feb-16	18	22	14	21	26
Mar-02	10	14	13	13	10
Mar-18	14	12	46	10	12
Apr-01	18	17	23	17	16
Apr-15	38	36	150	40	38
May-05	32	35	102	37	40
May-19	340	260	120	290	300
Jun-02	66	64	190	68	50
Jun-21	54	55	150	49	41
Jul-06	140	120	420	100	140
Jul-22	120	120	210	120	120
Aug-04	40	42	110	48	43
Aug-18	34	29	52	33	21
Sep-01	30	34	65	27	28
Sep-23	24	22	41	25	26
Oct-05	9	10	19	12	11
Oct-20	9	10	26	11	12
Nov-03	9	10	22	17	10
Nov-17	10	10	10	12	10
Dec-02	5	5	4	6	4
Dec-15	3	3	3	3	3

Table 6

Total Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1999

	Sampling Locations				
Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	420	420	590	440	440
Jan-21	400	400	1500	440	420
Feb-02	370	370	1430	400	390
Feb-16	380	380	450	400	400
Mar-02	430	410	1720	440	440
Mar-18	400	380	1850	400	390
Apr-01	480	380	1620	410	410
Apr-15	390	380	1770	410	390
May-05	440	430	1990	440	440
May-19	570	510	1530	540	520
Jun-02	440	440	2050	440	450
Jun-21	470	460	2100	470	460
Jul-06	370	360	1760	370	360
Jul-22	330	340	920	380	370
Aug-04	400	410	2130	430	430
Aug-18	400	390	2260	440	410
Sep-01	350	350	1920	380	380
Sep-23	320	320	1460	410	350
Oct-05	350	350	1140	360	360
Oct-20	330	330	1360	350	350
Nov-03	340	340	410	370	340
Nov-17	340	330	330	340	330
Dec-02	370	370	730	390	380
Dec-15	370	370	660	420	400

Table 7

Dissolved Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1999

	Sampling Locations				
Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	370	390	460	400	410
Jan-21	380	380	1410	410	400
Feb-02	350	350	1370	370	370
Feb-16	310	310	410	320	320
Mar-02	360	360	1590	390	380
Mar-18	350	340	1700	340	340
Apr-01	300	300	1490	340	320
Apr-15	310	310	1510	330	330
May-05	330	330	1710	340	330
May-19	230	240	1340	230	230
Jun-02	320	320	1710	330	330
Jun-21	330	340	1900	350	330
Jul-06	220	200	1220	200	200
Jul-22	180	190	620	190	190
Aug-04	310	310	1920	340	340
Aug-18	310	300	2100	340	330
Sep-01	280	270	1720	300	300
Sep-23	260	260	1320	330	270
Oct-05	290	300	1330	310	300
Oct-20	280	280	1250	310	300
Nov-03	300	300	310	310	290
Nov-17	280	280	280	280	280
Dec-02	300	320	670	330	330
Dec-15	330	340	620	390	360

Table 8

Suspended Solids (mg/L) Values for the Cedar River
near the Duane Arnold Energy Center during 1999

	Sampling Locations				
Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	3	3	110	3	4
Jan-21	2	2	12	3	3
Feb-02	5	4	21	4	5
Feb-16	54	53	13	54	52
Mar-02	32	30	12	30	30
Mar-18	36	30	63	32	29
Apr-01	48	51	32	45	42
Apr-15	62	55	170	56	56
May-05	70	73	130	84	73
May-19	310	260	120	280	290
Jun-02	91	110	250	91	96
Jun-21	94	88	220	88	96
Jul-06	130	130	480	150	130
Jul-22	150	150	250	160	160
Aug-04	66	67	120	68	68
Aug-18	75	71	68	75	78
Sep-01	62	65	86	67	71
Sep-23	50	47	65	50	49
Oct-05	30	31	30	31	29
Oct-20	31	28	40	29	28
Nov-03	26	29	85	60	28
Nov-17	29	29	25	30	29
Dec-02	10	11	3	10	13
Dec-15	6	6	3	6	10

Table 9

Dissolved Oxygen (mg/L) Values for the Cedar River
near the Duane Arnold Energy Center during 1999

Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	13.0	13.4	13.8	12.9	14.3
Jan-21	13.1	12.8	9.8	12.8	13.1
Feb-02	14.2	14.0	10.5	13.8	14.9
Feb-16	15.1	15.3	12.8	15.5	15.2
Mar-02	13.6	13.9	7.6	13.5	12.7
Mar-18	11.9	12.6	13.7	12.7	12.8
Apr-01	12.8	13.1	*	13.0	13.2
Apr-15	10.3	10.3	8.2	10.2	10.2
May-05	9.4	9.7	7.2	9.5	9.8
May-19	7.4	7.5	6.0	7.4	7.4
Jun-02	9.7	9.3	7.7	9.2	9.1
Jun-21	8.6	8.7	7.1	8.9	8.6
Jul-06	7.0	6.8	7.0	7.1	6.9
Jul-22	7.0	7.2	6.5	7.1	6.9
Aug-04	7.4	7.8	5.1	7.6	7.7
Aug-18	9.0	9.5	4.6	9.1	9.0
Sep-01	10.0	11.2	6.0	11.0	11.9
Sep-23	12.0	12.5	5.3	12.0	14.4
Oct-05	12.5	12.6	6.2	12.7	12.9
Oct-20	14.1	15.5	8.8	15.4	14.0
Nov-03	13.7	13.9	11.1	11.2	14.0
Nov-17	13.5	14.5	12.7	13.5	14.5
Dec-02	14.4	14.7	7.3	14.0	15.3
Dec-15	14.6	15.0	9.2	14.2	16.0

*Analytical error

Table 10

Carbon Dioxide (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1999

Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	4	4	3	4	4
Jan-21	10	5	*	5	6
Feb-02	13	5	*	6	5
Feb-16	6	7	5	4	2
Mar-02	4	3	*	4	4
Mar-18	<1	<1	*	<1	<1
Apr-01	2	2	*	2	<1
Apr-15	2	3	*	3	3
May-05	<1	<1	*	<1	<1
May-19	4	4	*	4	4
Jun-02	2	2	*	2	2
Jun-21	2	3	*	3	3
Jul-06	2	3	*	3	3
Jul-22	3	2	1	2	2
Aug-04	2	2	*	2	2
Aug-18	2	2	*	2	2
Sep-01	1	<1	2	<1	<1
Sep-23	<1	<1	*	<1	<1
Oct-05	<1	<1	*	<1	<1
Oct-20	<1	<1	*	<1	<1
Nov-03	<1	<1	<1	<1	<1
Nov-17	<1	<1	<1	<1	<1
Dec-02	<1	<1	4	<1	<1
Dec-15	<1	<1	<1	<1	<1

*Unable to calculate

Table 11

Total Alkalinity (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1999

	Sampling Locations				
Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	248	246	264	250	240
Jan-21	226	202	138	218	204
Feb-02	218	206	142	212	216
Feb-16	204	190	182	176	194
Mar-02	224	226	188	226	212
Mar-18	206	218	164	210	236
Apr-01	196	198	172	196	202
Apr-15	170	172	154	172	176
May-05	202	202	194	202	208
May-19	98	108	172	108	110
Jun-02	198	196	266	194	198
Jun-21	200	220	120	220	230
Jul-06	112	110	124	104	114
Jul-22	100	104	256	100	96
Aug-04	194	196	102	192	194
Aug-18	176	176	218	174	176
Sep-01	164	160	156	158	156
Sep-23	144	140	218	144	136
Oct-05	200	188	200	188	192
Oct-20	178	178	218	180	176
Nov-03	196	198	204	206	204
Nov-17	178	176	180	184	176
Dec-02	216	218	200	210	216
Dec-15	222	206	234	212	218

Table 12

Carbonate Alkalinity (mg/L $CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center during 1999

Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	<1	<1	<1	<1	<1
Jan-21	<1	<1	<1	<1	<1
Feb-02	<1	<1	<1	<1	<1
Feb-16	<1	<1	<1	<1	<1
Mar-02	<1	<1	<1	<1	<1
Mar-18	4	4	<1	4	4
Apr-01	<1	<1	<1	<1	6
Apr-15	<1	<1	<1	<1	<1
May-05	4	2	<1	4	4
May-19	<1	<1	<1	<1	<1
Jun-02	<1	<1	<1	<1	<1
Jun-21	<1	<1	<1	<1	<1
Jul-06	<1	<1	<1	<1	<1
Jul-22	<1	<1	<1	<1	<1
Aug-04	<1	<1	<1	<1	<1
Aug-18	<1	<1	<1	<1	<1
Sep-01	<1	2	<1	2	4
Sep-23	8	10	8	10	12
Oct-05	18	18	<1	16	16
Oct-20	8	12	<1	12	12
Nov-03	14	14	4	4	18
Nov-17	6	10	4	6	6
Dec-02	6	8	<1	6	8
Dec-15	8	6	8	6	6

Table13

Units of pH Values for the Cedar River
near the Duane Arnold Energy Center during 1999

Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	8.3	8.3	8.4	8.3	8.2
Jan-21	7.8	8.1	7.8	8.1	8.0
Feb-02	7.7	8.1	7.5	8.0	8.1
Feb-16	8.0	7.9	8.0	8.1	8.3
Mar-02	8.1	8.3	7.9	8.2	8.2
Mar-18	8.6	8.5	8.2	8.5	8.6
Apr-01	8.3	8.3	8.2	8.3	8.4
Apr-15	8.2	8.1	8.0	8.1	8.1
May-05	8.5	8.4	8.2	8.4	8.5
May-19	7.7	7.7	8.0	7.7	7.7
Jun-02	8.2	8.2	8.4	8.2	8.2
Jun-21	8.2	8.1	8.0	8.1	8.1
Jul-06	7.9	7.8	7.8	7.8	7.8
Jul-22	7.8	7.9	8.8	8.0	7.9
Aug-04	8.2	8.2	7.6	8.2	8.2
Aug-18	8.2	8.3	8.2	8.3	8.3
Sep-01	8.3	8.4	7.9	8.4	8.0
Sep-23	8.5	8.7	8.4	8.7	9.0
Oct-05	8.5	8.7	8.0	8.6	8.8
Oct-20	8.7	8.8	8.0	8.8	8.9
Nov-03	8.8	8.8	8.4	8.4	8.8
Nov-17	8.7	8.7	8.7	8.6	9.0
Dec-02	8.9	8.8	8.0	8.8	8.9
Dec-15	8.7	8.6	8.5	8.7	8.7

Table 14

Total Hardness (mg/L $CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center during 1999

Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	250	250	300	270	270
Jan-21	290	300	920	320	300
Feb-02	250	240	790	270	250
Feb-16	240	250	320	250	260
Mar-02	310	390	1100	350	340
Mar-18	220	320	920	240	300
Apr-01	230	250	890	250	240
Apr-15	200	220	930	250	260
May-05	280	330	1200	310	280
May-19	160	170	920	200	160
Jun-02	270	260	1200	270	270
Jun-21	270	270	1200	290	270
Jul-06	150	150	700	150	140
Jul-22	120	220	540	170	160
Aug-04	270	270	1200	310	270
Aug-18	250	250	1400	260	270
Sep-01	220	260	1100	330	250
Sep-23	200	200	880	240	210
Oct-05	260	250	860	250	250
Oct-20	250	250	820	260	270
Nov-03	260	260	300	280	260
Nov-17	260	260	260	260	260
Dec-02	300	290	500	300	300
Dec-15	290	290	450	320	300

Table 15

Calcium Hardness (mg/L $CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center during 1999

Date 1999	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	190	190	240	220	220
Jan-21	210	200	600	300	200
Feb-02	170	180	560	180	190
Feb-16	180	180	230	180	190
Mar-02	220	200	740	220	200
Mar-18	160	170	740	160	190
Apr-01	150	150	660	160	160
Apr-15	170	180	700	180	180
May-05	190	200	790	200	190
May-19	110	120	610	110	110
Jun-02	180	190	780	170	190
Jun-21	180	190	800	190	200
Jul-06	90	100	520	100	100
Jul-22	80	92	400	92	96
Aug-04	180	190	830	190	200
Aug-18	170	170	850	180	180
Sep-01	140	150	700	150	140
Sep-23	120	120	530	140	140
Oct-05	170	170	540	160	160
Oct-20	160	160	520	160	170
Nov-03	170	170	200	180	160
Nov-17	170	160	160	160	160
Dec-02	200	200	320	200	200
Dec-15	190	190	300	220	200

Table 16

Total Phosphorus (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center during 1999

Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	0.2	0.2	0.4	0.2	0.2
Jan-21	0.2	0.2	1.6	0.2	0.2
Feb-02	0.1	0.1	1.2	0.1	0.1
Feb-16	0.2	0.2	0.4	0.3	0.3
Mar-02	0.2	0.2	1.6	0.2	0.2
Mar-18	0.2	0.2	1.4	0.2	0.2
Apr-01	0.1	0.1	1.3	0.2	0.2
Apr-15	0.2	0.2	2.2	0.3	0.2
May-05	0.2	0.2	1.9	0.3	0.3
May-19	0.8	0.7	2.6	0.7	0.7
Jun-02	0.2	0.2	1.8	0.3	0.2
Jun-21	0.2	0.2	1.8	0.2	0.3
Jul-06	0.5	0.4	3.1	0.4	0.4
Jul-22	0.5	0.4	1.2	0.5	0.5
Aug-04	0.3	0.3	1.9	0.3	0.3
Aug-18	0.2	0.2	1.4	0.2	0.2
Sep-01	0.2	0.2	1.3	0.2	0.1
Sep-23	0.1	0.1	1.6	0.2	0.1
Oct-05	0.1	0.2	1.7	0.2	0.1
Oct-20	<0.1	<0.1	1.5	<0.1	<0.1
Nov-03	<0.1	<0.1	0.1	<0.1	<0.1
Nov-17	<0.1	0.1	0.2	0.2	0.2
Dec-02	0.2	0.2	0.7	0.2	0.2
Dec-15	0.1	<0.1	0.8	0.1	0.1

Table 17

Soluble Orthophosphate (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center during 1999

	Sampling Locations				
Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	0.2	0.2	0.2	0.2	0.2
Jan-21	0.2	0.2	0.6	0.2	0.2
Feb-02	<0.1	<0.1	0.6	0.1	0.1
Feb-16	0.1	0.1	0.2	0.1	0.1
Mar-02	0.1	0.1	1.1	0.1	0.1
Mar-18	0.1	0.1	0.1	0.1	0.1
Apr-01	<0.1	<0.1	0.7	<0.1	<0.1
Apr-15	0.2	0.2	1.3	0.2	0.2
May-05	<0.1	<0.1	0.9	<0.1	<0.1
May-19	0.1	0.1	1.2	0.1	0.1
Jun-02	<0.1	<0.1	<0.1	<0.1	<0.1
Jun-21	0.1	0.1	1.0	0.1	0.1
Jul-06	0.1	0.1	1.2	0.1	0.1
Jul-22	0.4	0.4	0.6	0.4	0.4
Aug-04	0.2	0.2	1.7	0.2	0.2
Aug-18	<0.1	<0.1	1.0	<0.1	<0.1
Sep-01	<0.1	<0.1	0.9	<0.1	<0.1
Sep-23	<0.1	<0.1	1.2	<0.1	<0.1
Oct-05	<0.1	<0.1	1.4	<0.1	<0.1
Oct-20	<0.1	<0.1	1.1	<0.1	<0.1
Nov-03	<0.1	<0.1	<0.1	<0.1	<0.1
Nov-17	<0.1	<0.1	<0.1	<0.1	<0.1
Dec-02	<0.1	<0.1	<0.1	<0.1	<0.1
Dec-15	0.1	<0.1	0.5	0.1	0.1

Table 18

Ammonia (mg/L-N) Values for the Cedar River
near the Duane Arnold Energy Center during 1999

	Sampling Locations				
Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	0.1	0.1	0.1	0.1	0.1
Jan-21	0.2	0.2	0.1	0.2	0.2
Feb-02	0.1	0.1	0.1	<0.1	0.1
Feb-16	0.1	0.1	0.2	0.1	0.1
Mar-02	<0.1	<0.1	<0.1	<0.1	<0.1
Mar-18	<0.1	<0.1	<0.1	<0.1	<0.1
Apr-01	<0.1	<0.1	<0.1	<0.1	<0.1
Apr-15	<0.1	<0.1	<0.1	<0.1	<0.1
May-05	<0.1	<0.1	0.2	<0.1	<0.1
May-19	0.2	0.2	0.2	0.2	0.2
Jun-02	<0.1	<0.1	0.2	<0.1	<0.1
Jun-21	<0.1	<0.1	<0.1	<0.1	<0.1
Jul-06	<0.1	<0.1	<0.1	<0.1	<0.1
Jul-22	<0.1	<0.1	<0.1	<0.1	<0.1
Aug-04	<0.1	<0.1	<0.1	<0.1	<0.1
Aug-18	<0.1	<0.1	0.1	<0.1	<0.1
Sep-01	<0.1	<0.1	0.5	<0.1	<0.1
Sep-23	<0.1	<0.1	0.3	<0.1	<0.1
Oct-05	<0.1	<0.1	0.2	<0.1	<0.1
Oct-20	<0.1	<0.1	0.5	<0.1	<0.1
Nov-03	<0.1	<0.1	<0.1	<0.1	<0.1
Nov-17	<0.1	<0.1	<0.1	<0.1	<0.1
Dec-02	<0.1	<0.1	0..4	<0.1	<0.1
Dec-15	<0.1	<0.1	<0.1	<0.1	<0.1

Table 19

Nitrate (mg/L)-N Values for the Cedar River
near the Duane Arnold Energy Center during 1999

Date 1999	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	7.9	7.8	8.1	7.9	7.8
Jan-21	7.1	7.0	24	7.4	7.2
Feb-02	6.5	6.4	14	6.7	6.5
Feb-16	8.5	8.5	9.4	8.8	8.6
Mar-02	7.3	7.5	20	7.5	7.3
Mar-18	6.7	6.5	19	6.7	6.4
Apr-01	5.8	5.6	15	6.0	6.1
Apr-15	12	12	36	12	12
May-05	9.5	9.5	35	9.8	9.6
May-19	7.5	8.1	38	8.0	7.9
Jun-02	9.9	9.8	35	10	9.6
Jun-21	11	11	81	11	11
Jul-06	6.4	5.6	20	5.8	5.9
Jul-22	3.1	3.2	9.2	3.3	3.3
Aug-04	6.9	6.7	6.9	6.9	6.8
Aug-18	4.9	4.9	23	5.1	5.0
Sep-01	4.7	4.6	19	4.8	4.7
Sep-23	3.4	3.3	11	3.9	3.4
Oct-05	4.0	3.9	11	3.9	3.9
Oct-20	3.2	3.1	6.4	3.1	3.1
Nov-03	3.3	3.1	2.7	2.6	3.1
Nov-17	3.0	3.0	2.7	2.7	3.0
Dec-02	4.3	4.2	4.0	4.3	4.4
Dec-15	4.4	4.3	3.1	4.5	4.4

Table 20

Total Iron (mg/L) Values for the Cedar River
near the Duane Arnold Energy Center during 1999

	Sampling Locations				
Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	0.11	0.10	2.1	0.15	0.19
Jan-21	0.10	0.09	0.54	0.13	0.11
Feb-02	0.18	0.15	0.87	0.17	0.19
Feb-16	2.0	1.9	0.77	2.2	2.0
Mar-02	1.1	1.1	0.95	1.2	0.99
Mar-18	0.92	1.2	2.1	1.3	1.1
Apr-01	0.96	0.88	0.92	0.83	0.78
Apr-15	2.4	2.1	7.2	2.1	2.2
May-05	2.8	2.9	6.1	2.8	3.6
May-19	15	13	5.1	13	12
Jun-02	3.1	3.2	8.7	3.6	3.3
Jun-21	3.4	3.5	9.8	3.5	3.8
Jul-06	5.7	5.8	22	5.9	5.8
Jul-22	6.6	6.6	11	7.2	6.9
Aug-04	2.7	2.8	5.6	2.7	2.7
Aug-18	1.3	1.5	1.9	1.3	1.4
Sep-01	1.1	0.94	2.4	1.2	1.2
Sep-23	0.44	0.52	1.0	0.51	0.44
Oct-05	0.30	0.29	0.54	0.28	0.26
Oct-20	0.18	0.18	1.3	0.21	0.20
Nov-03	0.17	0.19	1.20	0.87	0.17
Nov-17	0.21	0.21	0.21	0.29	0.21
Dec-02	0.20	0.18	0.27	0.57	0.18
Dec-15	0.15	0.14	0.21	0.16	0.20

Table 21

Biochemical Oxygen Demand (5 day in mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1999

	Sampling Locations				
Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	<1	1	<1	1	1
Jan-21	<1	<1	<1	<1	<1
Feb-02	<1	<1	<1	<1	1
Feb-16	2	2	2	1	1
Mar-02	<1	<1	1	<1	2
Mar-18	2	<1	2	2	1
Apr-01	5	5	5	5	5
Apr-15	<1	<1	2	<1	<1
May-05	2	3	4	2	3
May-19	2	2	3	2	2
Jun-02	1	2	3	2	1
Jun-21	1	1	2	1	1
Jul-06	3	1	2	<1	1
Jul-22	3	2	2	3	3
Aug-04	2	2	3	2	2
Aug-18	6	7	7	6	6
Sep-01	5	6	6	6	6
Sep-23	9	11	8	9	9
Oct-05	6	5	5	6	6
Oct-20	7	7	3	5	8
Nov-03	4	4	6	7	4
Nov-17	7	5	4	7	7
Dec-02	<1	<1	2	<1	<1
Dec-15	2	2	3	2	3

Table 22

Coliform Bacteria (Fecal Organisms/100 ml) Values for the Cedar River near the Duane Arnold Energy Center during 1999

Date 1999	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	1200	580	580	510	520
Jan-21	240	120	110	160	200
Feb-02	250	150	60	170	90
Feb-16	350	200	45	240	190
Mar-02	40	40	9	50	60
Mar-18	10	10	18	<10	<10
Apr-01	<10	20	20	<10	<10
Apr-15	250	200	400	280	280
May-05	190	90	550	150	170
May-19	1400	850	1300	1100	1000
Jun-02	3300	3500	1200	1500	2100
Jun-21	200	220	120	220	230
Jul-06	1300	1400	9500	1400	1500
Jul-22	3100	3600	350	4300	3500
Aug-04	290	260	240	340	340
Aug-18	120	60	140	100	91
Sep-01	170	160	50	130	130
Sep-23	110	150	500	120	60
Oct-05	20	20	560	30	20
Oct-20	110	100	260	30	70
Nov-03	10	<10	60	30	<10
Nov-17	20	<10	45	140	<10
Dec-02	10	10	320	20	64
Dec-15	55	10	280	20	10

Table 23

Coliform Bacteria (E. coli/100 ml) Values for the Cedar River near the Duane Arnold Energy Center during 1999

	Sampling Locations				
Date 1999	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
110	1	2	5	3	4
Jan-07	870	530	430	520	470
Jan-21	150	140	70	82	150
Feb-02	240	130	30	150	60
Feb-16	150	130	45	220	130
Mar-02	110	50	<10	40	20
Mar-18	10	20	10	<10	10
Apr-01	30	<10	60	10	<10
Apr-15	230	140	150	180	110
May-05	200	150	470	130	140
May-19	1100	1100	1100	890	1100
Jun-02	2000	1500	830	1300	1300
Jun-21	190	230	50	160	110
Jul-06	1400	1200	2200	1100	1200
Jul-22	1800	2000	380	270	1400
Aug-04	260	210	140	180	140
Aug-18	100	60	60	60	27
Sep-01	18	70	82	60	60
Sep-23	50	82	140	20	<10
Oct-05	10	<10	350	<10	20
Oct-20	<10	20	310	<10	<10
Nov-03	18	10	91	70	<10
Nov-17	20	20	<10	160	270
Dec-02	10	27	400	20	40
Dec-15	20	20	310	50	10

Table 24

Additional Chemical Analysis-1999

Station	Cl (mg/L)	SO_4 (mg/L)	Metals (ug/L) Cr	Cu	Pb	Mn	Hg	Zn
			Apr-15					
1. Lewis Access	23	26	<20	<10	<10	100	<1	60
2. Upstream DAEC	23	26	<20	<10	<10	80	<1	40
3. Downstream DAEC	23	32	<20	<10	<10	80	<1	20
4. One-half mile below plant	24	26	<20	<10	<10	90	<1	20
5. Discharge Canal	78	670	<20	20	<10	270	<1	100
			Jul-06					
1. Lewis Access	12	14	<20	<10	<10	150	<1	<20
2. Upstream DAEC	12	14	<20	<10	<10	150	<1	<20
3. Downstream DAEC	12	16	<20	<10	<10	150	<1	<20
4. One-half mile below plant	11	15	<20	<10	<10	150	<1	<20
5. Discharge Canal	57	550	30	20	<10	560	<1	100

Table 25

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Engery Center
8/18/99 - 9/23/99

Taxon	Collection Site				
	Lewis Access*	U/S DAEC	D/S DAEC	1/2 mile D/S	Discharge Canal
Nematoda		6	8	15	
Annelida					
Oligochaeta					
Naididae				5	
Tubificidae					1010
Arthropoda					
Insecta					
Coleoptera (Beetles)					
Dryopidae					
Helichus striatus		2	2		
Elmidae					
Macronychus spp.		2			
Stenelmis spp.		2			
Diptera					
Chironomidae		1685	1010	1090	510
Empididae					
Hemerodromia spp		55	14	6	
Simuliidae					
Simulium spp.		30	4		10
Ephemeroptera (Mayflies)					
Baetidae					
Baetis intercalaris		18	38	4	
Falceon quilleri		4			
Labiobaetis longipalpus		14	6	6	
Caenidae					
Amercaenis ridens			6	8	
Caenis hilaris		2	2	14	
Heptageniidae					
Heptagenia flavescens		100	218	94	
Stenonema mexicanum		52	80	42	
Stenonema terminatum		122	162	80	
Isonychiidae					
Isonychia spp.		38	78	34	
Tricorythidae					
Tricorythodes spp.		12	12		
Plecoptera (Stoneflies)					
Perlidae					
Acroneuria abnormis			2	2	
Attaneuria ruralis		2			
Trichoptera (Caddisflies)					
Brachycentridae					
Brachycentrus numerosus		2		2	
Hydropsychidae					
Cheumatopsyche spp.			2	4	
Hydropsyche bidens		774	450	518	
Hydropsyche orris		66	36	44	
Hydropsyche phalerata				2	
Hydropsyche simulans		90	104	74	
Potamyia flava		58	46	44	
Total Organisms		**3,136**	**2,280**	**2,088**	**1,530**
No. Organisms/m^2		**31,360**	**22,800**	**20,880**	**15,300**

*No samplers retrieved from this site (probably removed or tampered with by boaters/fishermen)

Table 25 (con't)

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Engery Center
9/23/99 - 10/29/99

Taxon	Collection Site Lewis Access	U/S DAEC	D/S DAEC	1/2 mile D/S	Discharge Canal
Platyhelminthes					
Turbellaria					
Planariidae					
Dugesia sp.			1		
Nematoda		1	1		
Annelida					
Oligochaeta					
Naididae		11	5	14	
Arthropoda					
Crustacea					
Isopoda					
Asellidae					
Caecidotea sp.				1	
Insecta					
Coleoptera (Beetles)					
Elmidae					
Macronychus spp.				1	
Stenelmis spp.		1			
Diptera					
Chironomidae	23	276	64	49	18
Empididae					
Chelifera spp			1	1	
Simuliidae					
Simulium spp.	26	8	4	1	
Ephemeroptera (Mayflies)					
Baetidae					
Baetis intercalaris		1			
Caenidae					
Caenis hilaris		1			
Heptageniidae					
Heptagenia flavescens	8	27	14	59	1
Stenonema mexicanum		3	2	1	
Stenonema terminatum	1	40	22	31	
Isonychiidae					
Isonychia spp.		1	2		
Tricorythidae					
Tricorythodes spp.			1		
Plecoptera (Stoneflies)					
Perlidae					
Acroneuria abnormis				1	
Perlodidae					
Isoperla spp. (prob bilineata)	4	6	7	11	
Taeniopterygidae					
Taeniopteryx spp.	4	53	16	8	
Trichoptera (Caddisflies)					
Brachycentridae					
Brachycentrus numerosus				1	
Hydropsychidae					
Cheumatopsyche spp.			1		
Hydropsyche bidens	24	87	69	75	
Hydropsyche orris	7	12	5	9	
Hydropsyche phalerata	4				
Hydropsyche simulans	22	15	15	17	
Potamyia flava	87	27	11	8	
Total Organisms	**210**	**569**	**241**	**288**	**19**
No. Organisms/m^2	**2,100**	**5,690**	**2,410**	**2,880**	**190**

Table 26

Daily Numbers of Fish Impinged at the Duane Arnold Energy Center
January - December 1999

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	6	4	18	0	1	0	0	0	1	0	0	0
2	0	1	7	0	0	1	0	0	0	0	0	0
3	0	0	14	3	0	0	0	0	0	0	0	3
4	0	5	8	3	0	0	0	0	0	0	0	0
5	1	3	6	0	0	0	0	1	0	1	0	0
6	3	7	2	3	0	0	0	1	0	0	0	0
7	0	3	7	0	0	0	1	0	0	0	0	0
8	0	8	4	0	1	0	0	0	0	0	0	0
9	0	8	6	0	0	0	0	0	0	0	0	0
10	0	11	5	0	0	0	0	0	0	0	0	0
11	0	14	18	3	0	0	0	0	0	0	0	0
12	0	7	20	0	0	0	0	0	0	0	0	2
13	0	4	2	0	0	0	0	0	0	0	0	0
14	0	0	10	0	0	0	0	0	0	0	0	0
15	0	0	9	0		0	0	0	0	0	0	0
16	0	2	3	0	0	0	2	0	0	0	0	0
17	0	0	15	1	1	0	0	0	0	0	0	0
18	0	0	4	0	1	0	0	0	0	0	0	1
19	0	0	14	0	0	0	0	0	0	0	0	0
20	0	3	2	0	0	0	*	0	0	0	0	0
21	0	10	3	2	0	0	0	0	0	0	0	4
22	0	*	2	1	0	1	0	0	0	0	0	0
23	0	7	3	1	0	0	0	0	0	0	0	0
24	0	*	0	0	0	0	0	0	0	0	0	0
25	0	19	0	0	1	1	*	0	0	0	0	0
26	0	10	0	0	2	0	1	1	0	0	0	0
27	0	9	5	0	0	0	0	0	0	0	0	1
28	1	12	0	0	0	0	0	1	0	0	0	5
29	0	-	2	1	0	0	0	0	0	1	0	0
30	0	-	0	0	0	0	0	0	0	0	0	5
31	0	-	0	-	0	-	0	0	-	0	-	3
Total	11	147	189	18	7	3	4	4	1	2	0	26

Total Annual 412

*No data

Table 27

Comparison of Average Values for Several Parameters at Upstream, Downstream and Discharge Canal Locations at the Duane Arnold Energy Center During Periods of Station Operation-1999

Parameters	Upstream (Station 2)	Discharge Canal (Station 5)	Downstream (Station 4)
Temperature (°C)	12.5	18.2	12.6 (101%)
Dissolved Solids (mg/L)	304	1335	319 (105%)
Total Hardness (mg/L)	240	774	255 (106%)
Total Phosphate (mg/L)	0.22	1.52	0.23 (105%)
Nitrate (mg/L as N)	6.5	20.4	6.6 (102%)
Iron (mg/L)	2.23	4.15	2.25 (101%)

*Percent of upstream level ()

Table 28

Comparison of Average Yearly Values for Several Parameters in the Cedar River Upstream of the Duane Arnold Energy Center*
1972-1999

Year	Mean flow** (cfs)	Turbidiity (NTU)	Total PO_4 (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)	Total Hardness (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7	253
1973	7,900	28	0.84	0.36	1.5	4.0	250
1974	5,580	29	2.10	0.17	4.2	4.7	266
1975	4,206	58	1.08	0.33	2.8	6.5	251
1976	2,082	41	0.25	0.25	2.8	7.3	233
1977	1,393	15	0.33	0.52	2.9	6.5	243
1978	3,709	23	0.26	0.22	4.4	3.3	261
1979	7,041	26	0.29	0.12	6.6	2.5	272
1980	4,523	40	0.34	0.19	5.4	4.3	238
1981	3,610	33	0.77	0.24	6.0	6.5	279
1982	7,252	43	0.56	0.23	8.0	5.1	274
1983	8,912	22	0.25	0.10	8.6	3.3	259
1984	7,325	40	0.32	0.10	5.9	3.9	264
1985	3,250	30	0.31	0.11	4.8	6.7	245
1986	6,475	33	0.26	0.10	6.8	3.7	285
1987	2,625	32	0.24	0.06	5.6	5.8	269
1988	1,546	28	0.30	<0.16	2.8	9.6	246
1989	947	24	0.37	<0.30	1.5	10.3	224
1990	5,061	33	0.29	<0.20	7.3	4.8	283
1991	8,085	65	0.38	<0.20	7.9	4.3	268
1992	5,717	49	0.31	<0.16	6.4	5.5	261
1993	15,900	44	0.27	<0.16	6.2	2.3	276
1994	4,701	34	0.28	<0.22	5.1	5.3	269
1995	4,384	31	0.21	<0.17	5.5	4.0	275
1996	3,200	34	0.29	<0.21	4.7	7.0	254
1997	4,996	38	0.3	<0.24	5.1	5.7	248
1998	6,024	41	0.26	<0.10	7.4	2.8	287
1999	7,786	43	0.21	<0.10	6.2	<3.1	242

*Data from Lewis Access location (Station 1)

**Data from U.S. Geological Survey Cedar Rapids gauging station

REFERENCES

1. McDonald, D.B., "Cedar River Baseline Ecological Study Annual Report, April 1971-April 1972. Duane Arnold Energy Center." Report prepared for Iowa Electric Light and Power Company by the University of Iowa, 1972.

2. McDonald, D.B., "Cedar River Baseline Ecological Study Annual Report, May 1972-April 1973. Duane Arnold Energy Center." Report prepared for Iowa Electric Light and Power Company by the University of Iowa, 1973.

3. McDonald, D.B., "Cedar River Baseline Ecological Study Final PreOperational Report, May 1973-January 1974". Report prepared for Iowa Electric Light and Power Company by the University of Iowa, 1974.

4. McDonald, D.B., "Cedar River Baseline Ecological Study Annual Operational Report, January 1974-January 1975. Duane Arnold Energy Center." Report prepared for Iowa Electric Light and Power Company by the University of Iowa, 1975.

5. McDonald, D.B., "Cedar River Baseline Ecological Study Annual Report, January 1975-January 1976. Duane Arnold Energy Center." Report prepared for Iowa Electric Light and Power Company by the University of Iowa, 1976.

6. McDonald, D.B., "Cedar River Baseline Ecological Study Annual Report, January 1976-December 1976. Duane Arnold Energy Center." Report prepared for Iowa Electric Light and Power Company by the University of Iowa, 1977.

7. McDonald, D.B., "Cedar River Baseline Ecological Study Annual Report, January 1977-December 1977. Duane Arnold Energy Center." Report prepared for Iowa Electric Light and Power Company by the University of Iowa, 1978.

8. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1978-December 1978." In: Reports of Environmental Monitoring Program, January 1978-December 1978, Iowa Electric Light and Power Company, 1979.

9. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1979-December 1979." Report prepared for Iowa Electric Light and Power Company by D.B. McDonald Research, Inc., May 1980.

10. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1980-December 1980." Report prepared for Iowa Electric Light and Power Company by D.B. McDonald Research, Inc., June 1981.

11. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1981-December 1981." Report prepared for Iowa Electric Light and Power Company, May 1982.

12. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1982-December 1982." Report prepared for Iowa Electric Light and Power Company, May 1983.

13. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1983-December 1983." Report prepared for Iowa Electric Light and Power Company, March 1984.

14. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1984-December 1984." Report prepared for Iowa Electric Light and Power Company, April 1985.

15. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1985-December 1985." Report prepared for Iowa Electric Light and Power Company, May 1986.

16. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1986-December 1986." Report prepared for Iowa Electric Light and Power Company, April 1987.

17. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1987-December 1987." Report prepared for Iowa Electric Light and Power Company, April 1988.

18. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1988-December 1988." Report prepared for Iowa Electric Light and Power Company, March 1989.

19. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1989-December 1989." Report prepared for Iowa Electric Light and Power Company, March 1990.

20. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1990-December 1990." Report prepared for Iowa Electric Light and Power Company, March 1991.

21. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1991-December 1991." Report prepared for Iowa Electric Light and Power Company, March 1992.

22. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1992-December 1992." Report prepared for Iowa Electric Light and Power Company, March 1993.

23. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1993-December 1993." Report prepared for I.E.S. Utilities Inc., March 1994.

24. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1994-December 1994." Report prepared for I.E.S. Utilities Inc., March 1995.

25. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1995-December 1995." Report prepared for I.E.S. Utilities Inc., March 1996.

26. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1996-December 1996." Report prepared for I.E.S. Utilities Inc., March 1997.

27. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1997-December 1997." Report prepared for I.E.S. Utilities Inc., March 1998.

28. McDonald, D.B., "Duane Arnold Energy Center Cedar River Operational Ecological Study Annual Report, January 1997-December 1998." Report prepared for Alliant Energy Co., March 1999.

29. State of Iowa, "Water Quality Standards." Chapter 61, 567, Iowa Administrative Code. State of Iowa, Des Moines, Iowa, June 1995.

30. U.S. Army Corp of Engineers, "The Zebra Mussels: Biology, Ecology and Recommended Control Strategies." Tech. Note ZMR-1-01, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, March 1992.

31. U.S. Army Corp of Engineers, "The Zebra Mussels at Lock and Dam 6, Upper Mississippi River, January 1994." Tech. Note ZMR-1-23, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, December 1994.

32. U.S. Army Corp of Engineers, "Zebra Mussel Densities in St. Paul District, 1991-1994". Tech. Note ZMR-1-30 U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi October 1995.

33. Johnson, J.K., Institute of Hydraulic Research, University of Iowa, Verbal Communication, March 2000.